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# **Volatilization and Steam-Enhanced Biodegradation of VOC-TPH LNAPL Mixture**

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# Objective



**Present an overview of a complex remedial approach at Building 379, Naval Air Station North Island (NASNI) in San Diego, CA, including:**

- **Soil vapor extraction (SVE) using horizontal wells under Building 379 to extract soil vapor with elevated levels of Total Petroleum Hydrocarbons (TPH) and chlorinated Volatile Organic Compounds (cVOCs)**
- **Volatilization of light non-aqueous phase liquid (LNAPL) with SVE**
- **Biodegradation of TCE in LNAPL**
- **Enhancement of volatilization and biodegradation due to heat radiation from Base steam line**
- **Future enhancement by injecting steam under LNAPL**

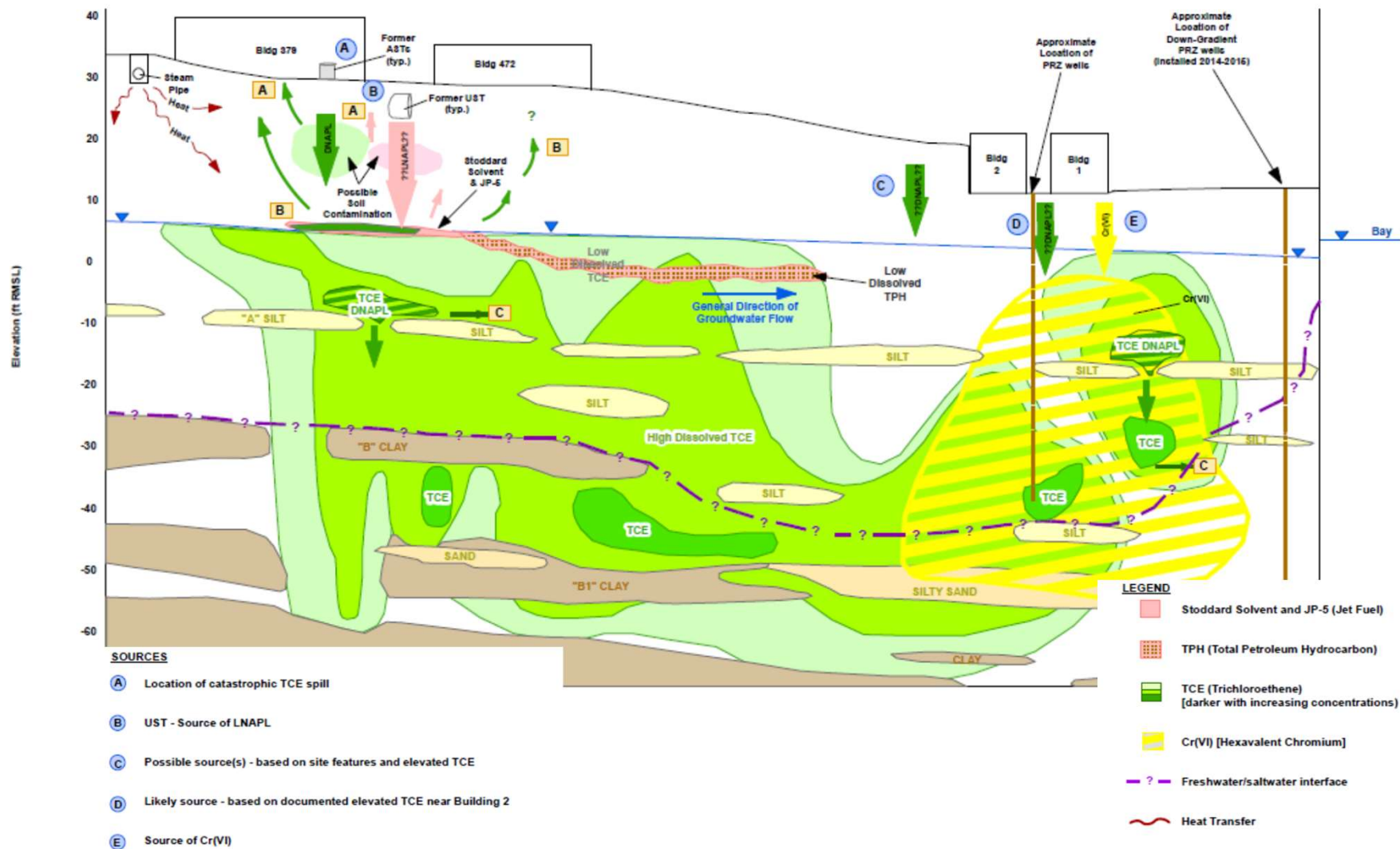
# Background



## Summary of Site Conditions and Issues:

- Building 379 has a footprint of 172,000 square feet and partially overlies a LNAPL plume
- Groundwater is at 23 feet bgs
- LNAPL is comprised of TPH (jet fuel and Stoddard solvent) mixed with cVOCs: primarily trichloroethene (TCE), and 1,1,1 trichloroethane (1,1,1-TCA)
- Estimates of LNAPL volumes range from tens to hundreds of thousands of gallons, >98% TPH, and <2% cVOCs
- A portion of the LNAPL plume is at temperatures above 100°F due to a steam line (which is at 6 feet bgs)

# Background – Conceptual Site Model



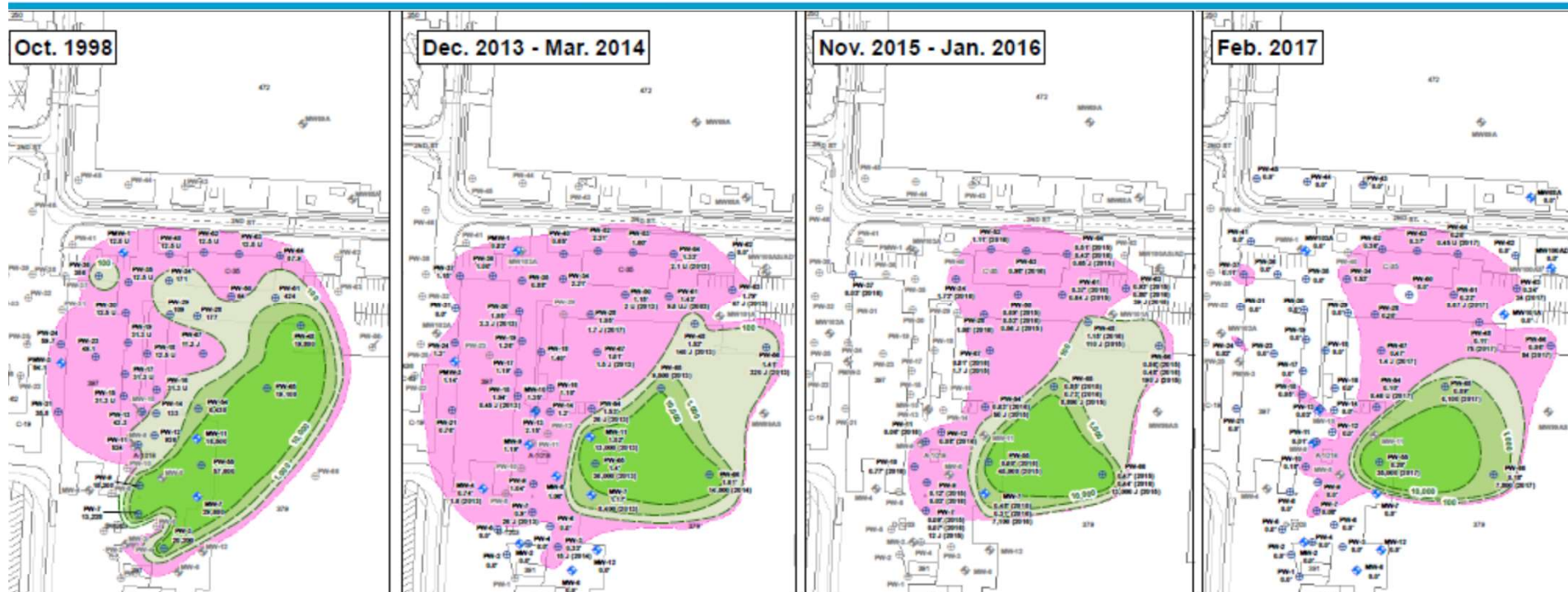
# Background (Cont'd)



## Summary of Site Conditions and Issues:

- Volatilization of the LNAPL has resulted in sub-slab soil vapor concentrations  $> 10,000,000 \mu\text{g}/\text{m}^3$  (likely exacerbated due to elevated LNAPL temperatures)
- cVOCs represent approximately 50% of the soil vapor concentrations even though  $< 2\%$  of LNAPL is cVOCs
- cVOCs are the main risk driver (specifically TCE); and are present in sub-slab soil vapor at several orders of magnitude above project screening levels
- Elevated TCE concentrations in sub-slab soil vapor caused TCE concentrations in indoor air to exceed action levels, resulting in voluntary relocation of some personnel

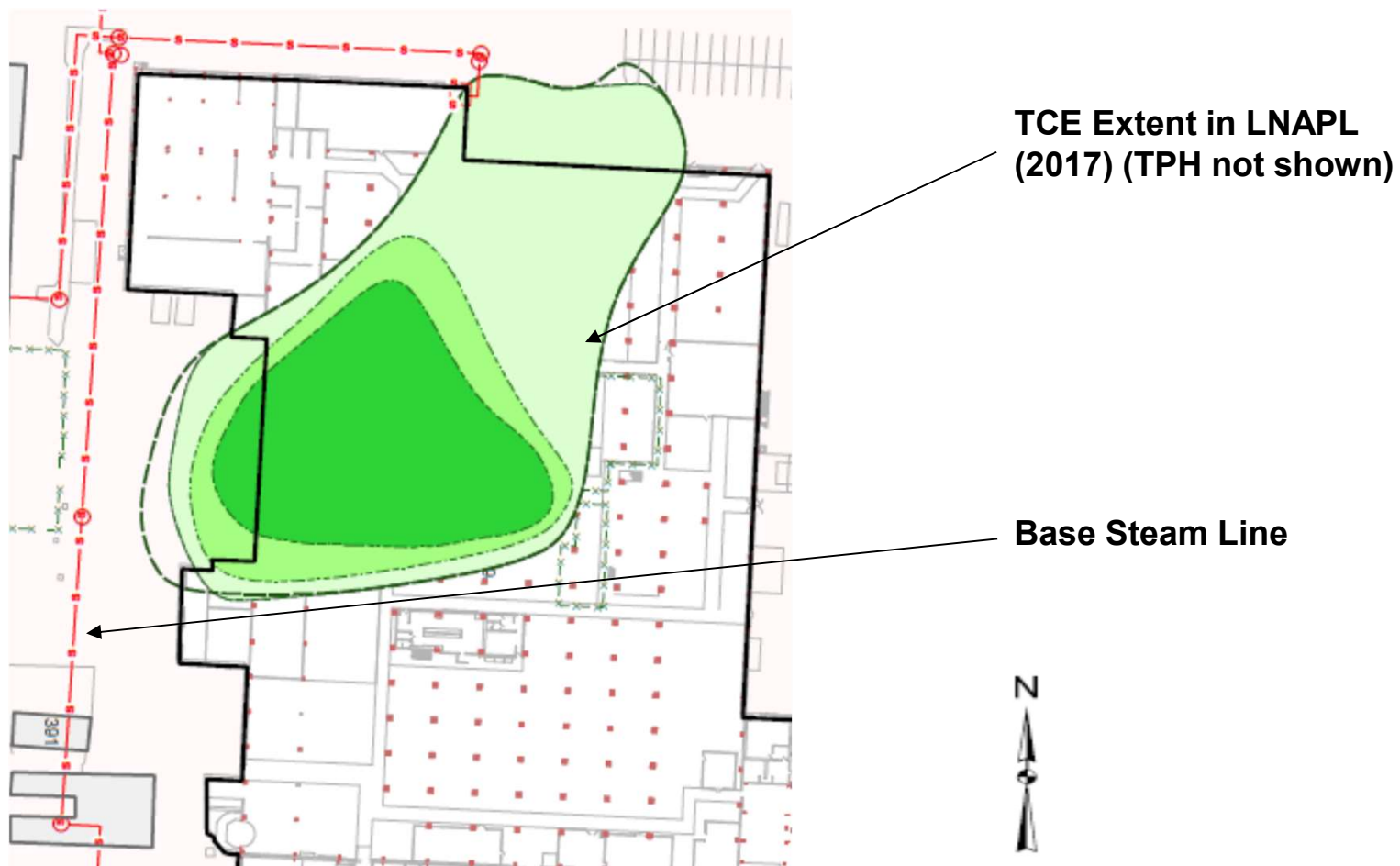
# LNAPL Extent over Time



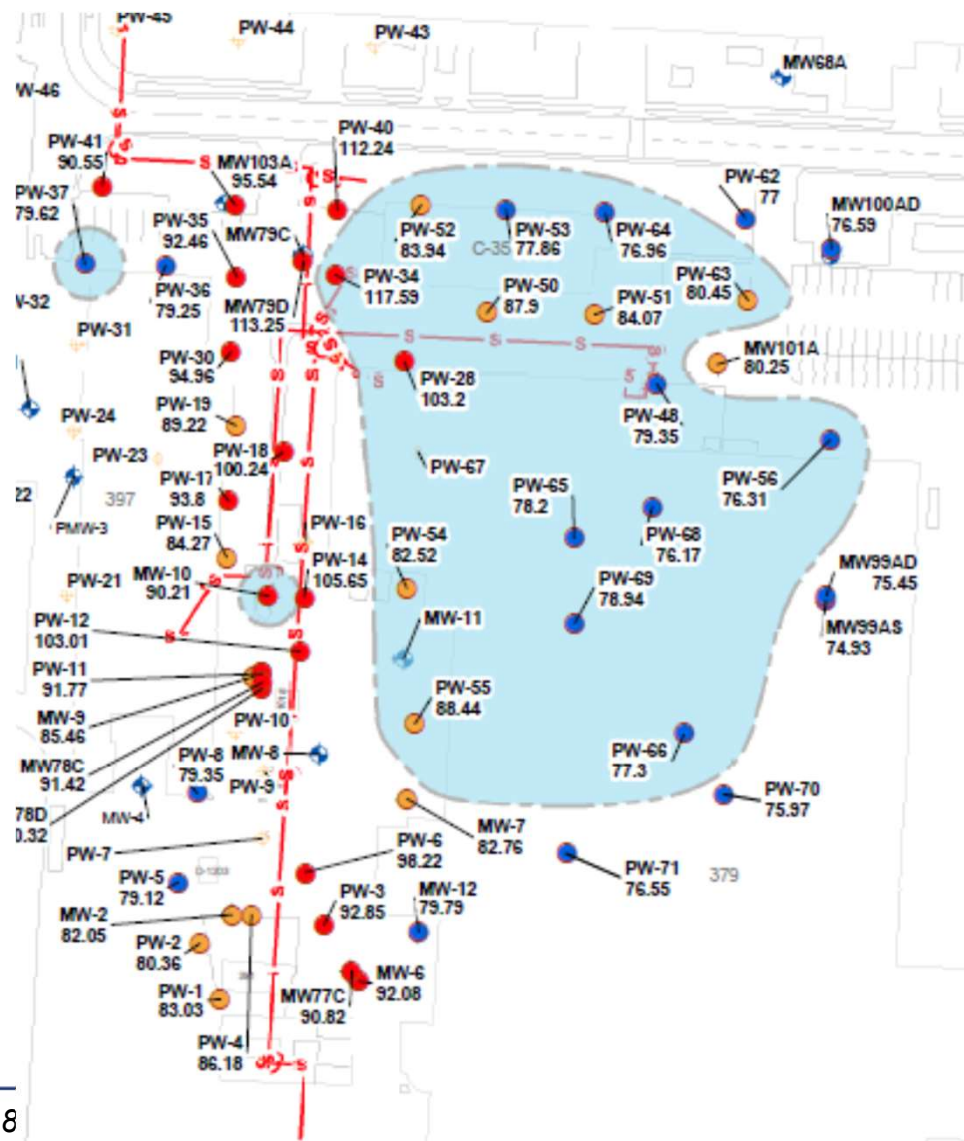
- TCE Isoconcentration in LNAPL (mg/kg)
- 100 mg/kg
- 1,000 mg/kg
- 10,000 mg/kg
- Extent of LNAPL



# Proximity of Steam Line

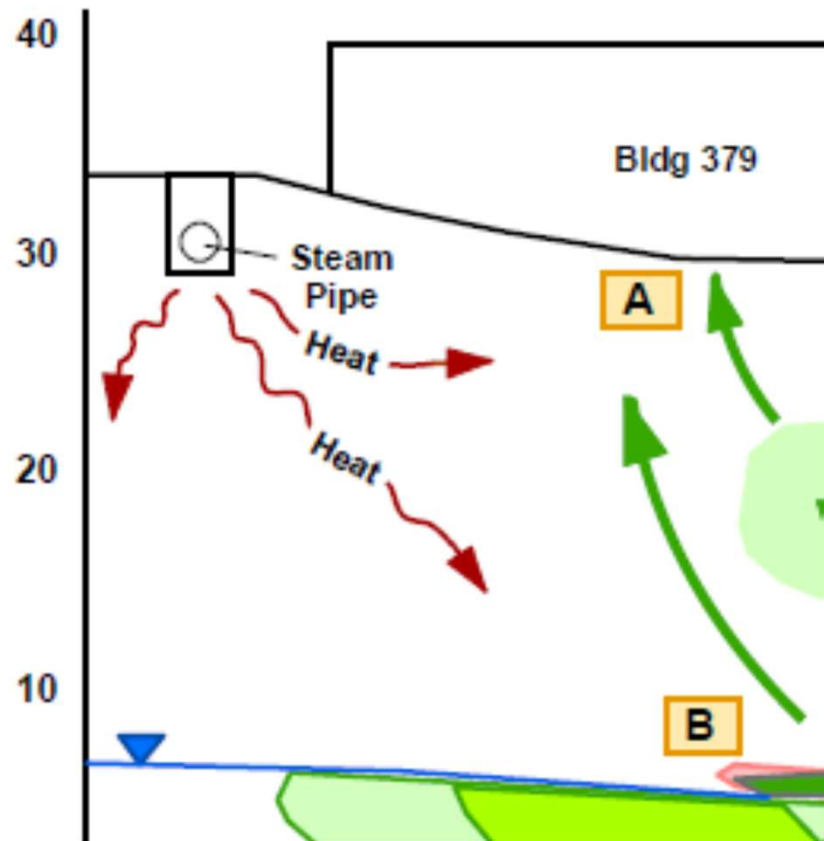


# LNAPL/GW Temperatures (2018)





# LNAPL/GW Temperatures (2018)



- The heat from the steam pipe has radiated through the soil (~20 feet vertically)
- Laterally, increased temperatures are observed at least 30 feet away from the steam pipe

***It is hypothesized that the problem with elevated VOCs under the sub-slab are exacerbated due to steam***

# Remedial Activities 2016



- A soil vapor extraction (SVE) system has been in operation since May 2016, consisting of:
  - Two horizontal wells under the northern portion of the building at 10 feet bgs
  - A vapor extraction and treatment system that uses compression and refrigeration to condense the TPH/cVOCs in extracted vapor to liquid product



# SVE Results: Vacuum Influence

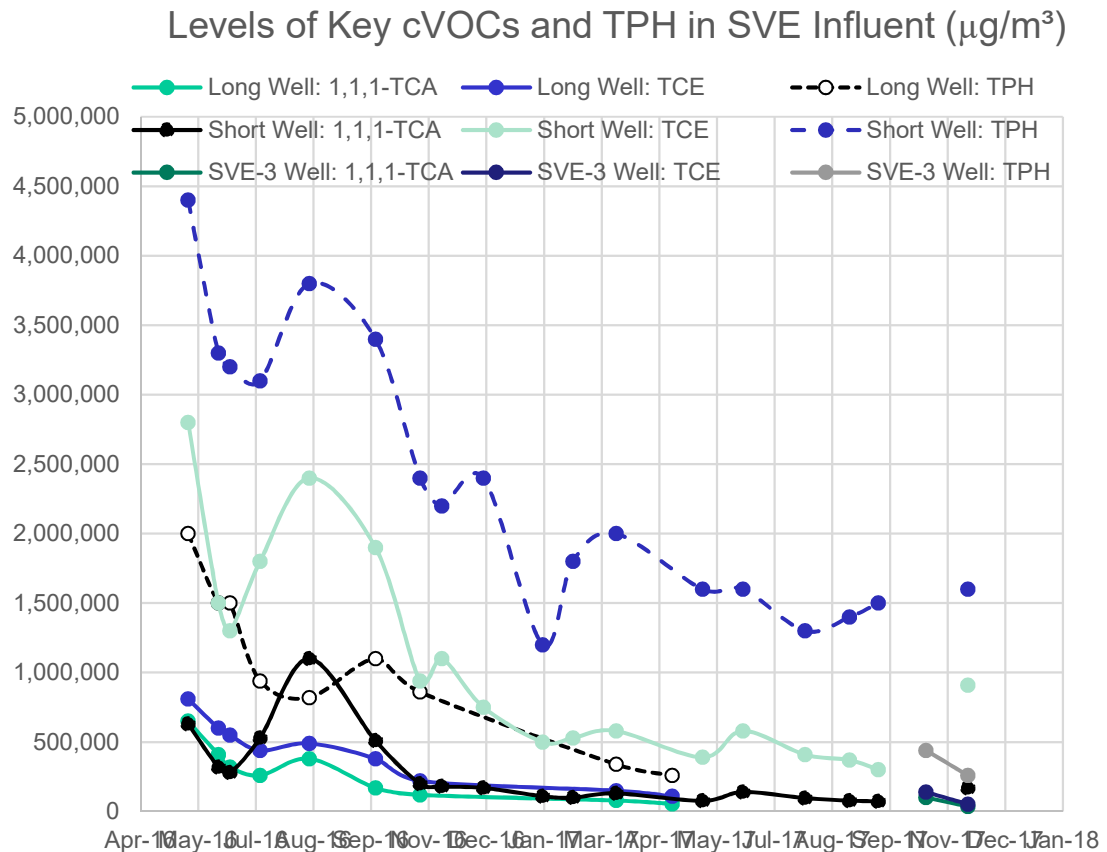


- Laterally, vacuum responses were observed over 100 feet away from the SVE wells (well depth is 10 feet bgs)
- Vertically, vacuum responses were observed at 20 feet bgs
- Both lateral and vertical radius of vacuum influence (ROVI) were much better than expected: likely due to sealing of over 15,000 linear feet of cracks and joints (which would reduce short-circuiting) which was a separate TCRA action
- Vacuum monitoring probes were initially planned to be only at 5 and 10 feet bgs, a few locations were extended to 15 and 20 feet bgs at the last minute

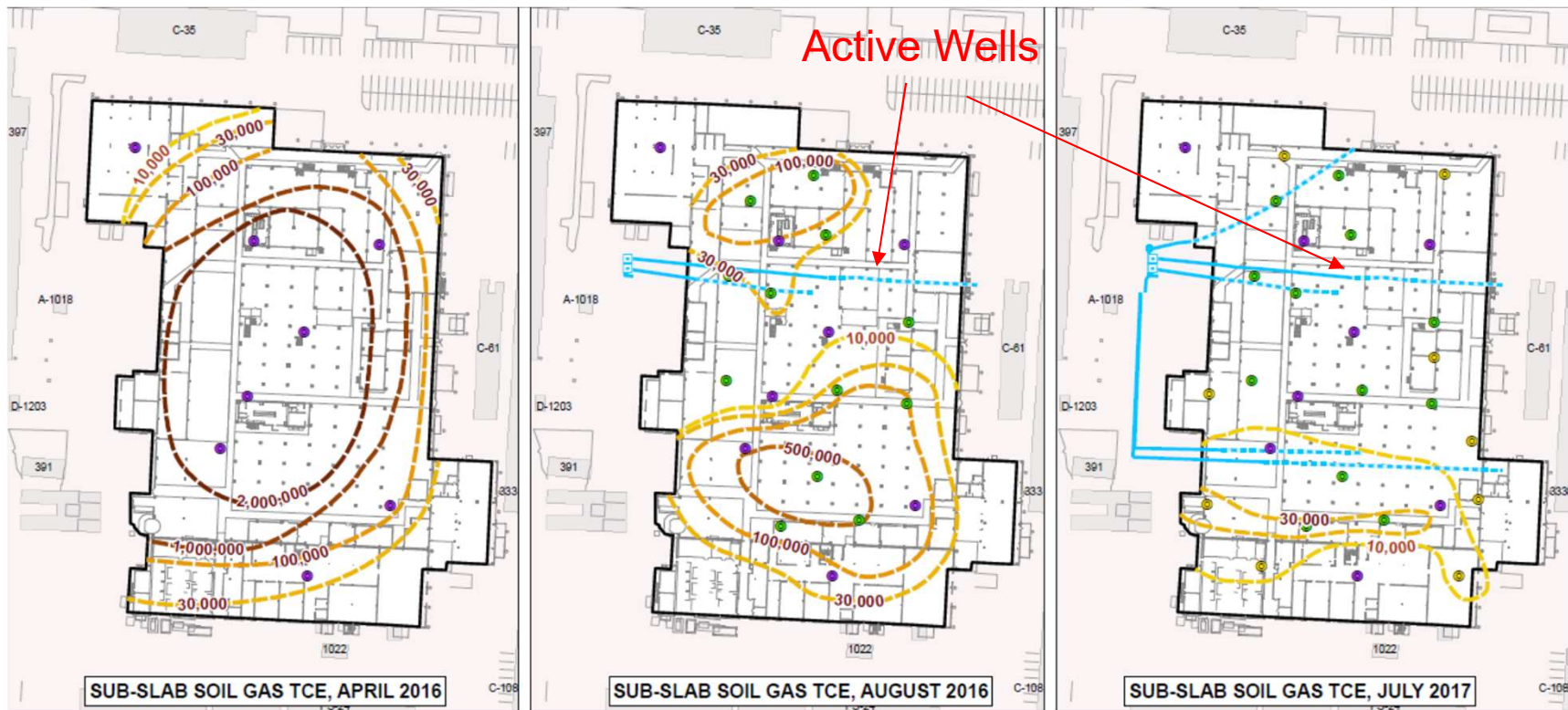
# SVE Results: Extraction Metrics



- More than approximately 14,000 lbs of TPH/cVOCs have been recovered and recycled by the SVE system
- A significant decrease in indoor air concentrations was observed within a few weeks of startup (below action levels)
- Levels of cVOCs and TPH in extracted vapor have decreased significantly (but still above 1,000,000  $\mu\text{g}/\text{m}^3$ )



# SVE Results: Sub-slab TCE



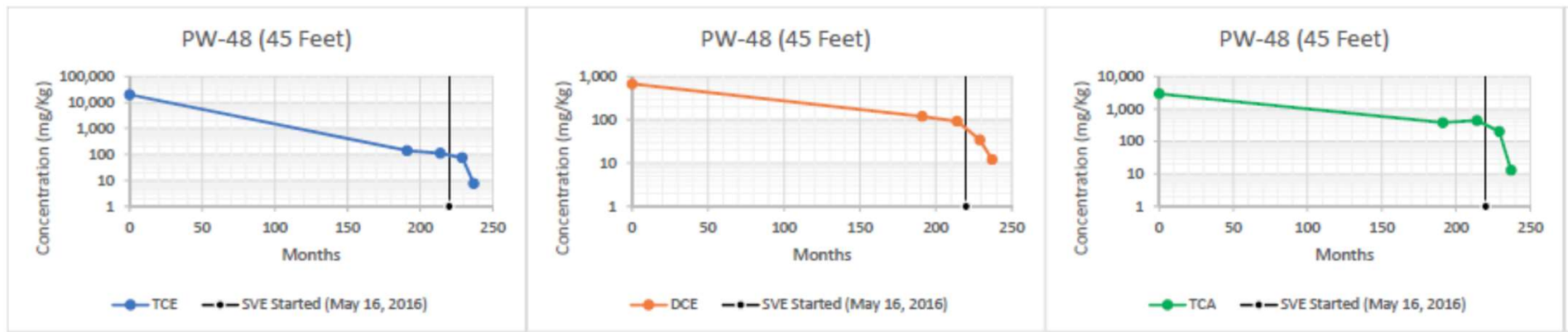
- TCE footprint decreased after 15 months of operation of 2 wells
- Samples were collected under “dynamic” conditions, i.e., SVE wells were extracting



# Effect of SVE on cVOCs in LNAPL



- Significant decrease in cVOCs in LNAPL due to SVE (Note – the SVE wells are ~ 13 feet above the top of LNAPL)
- Decreases in LNAPL thickness were also observed
- cVOCs in extracted vapor at 50%, vs. 2% within LNAPL
- cVOCs are decreasing within LNAPL at a much greater rate than TPH



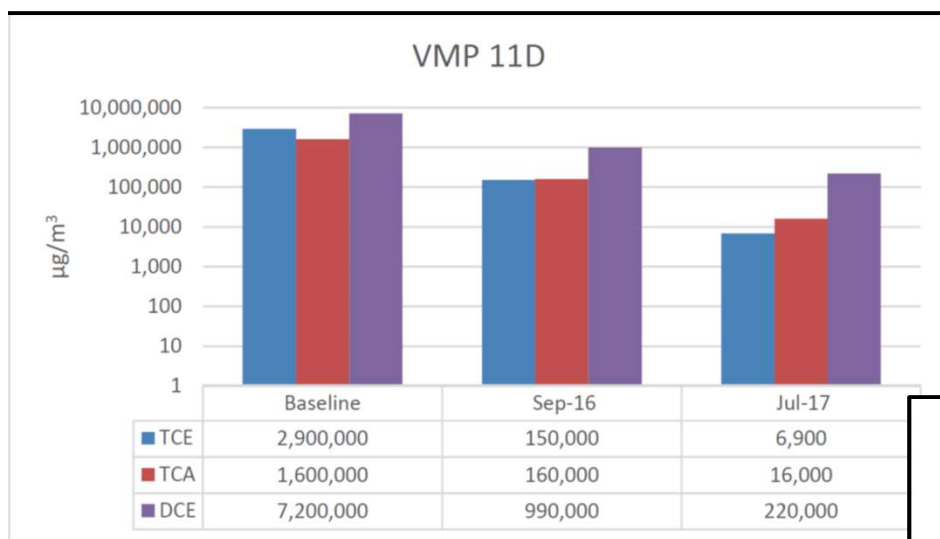
Notes:  
Months = 0 is January 20, 1998  
Distance from Nearest Steam Line in Title

# Degradation of TCE in LNAPL?



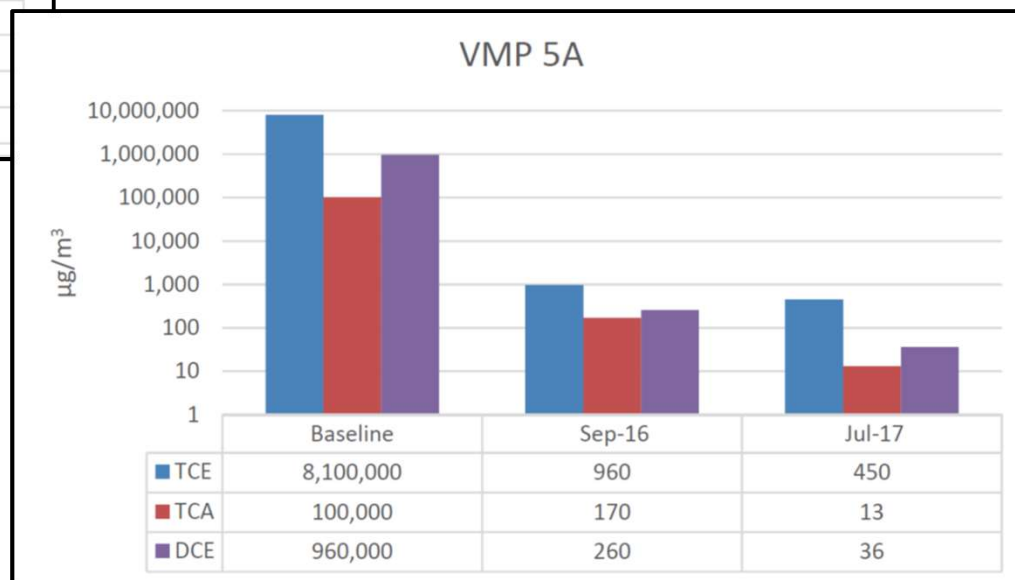
- Significant levels of cDCE were detected in soil vapor, both in sub-slab and at depth – this is most likely due to biodegradation of TCE
- There is ample electron donor (TPH in the Jet Fuel and Stoddard Solvent)
- Biodegradation of TCE was confirmed in bench scale treatability tests (unamended controls showed decrease in TCE coupled with increase in cDCE)
- Currently, levels of cDCE>TCE in soil vapor probes that are close to the Base steam line, whereas TCE>cDCE away from steam line

# Degradation of TCE in LNAPL?



VMP 11D is ~ 15 feet from Steam Line  
DCE>TCE

VMP 5A is ~ 100 feet from Steam Line  
TCE>DCE



# Steam: Friend or Foe?



Initially, steam was considered to be a foe:

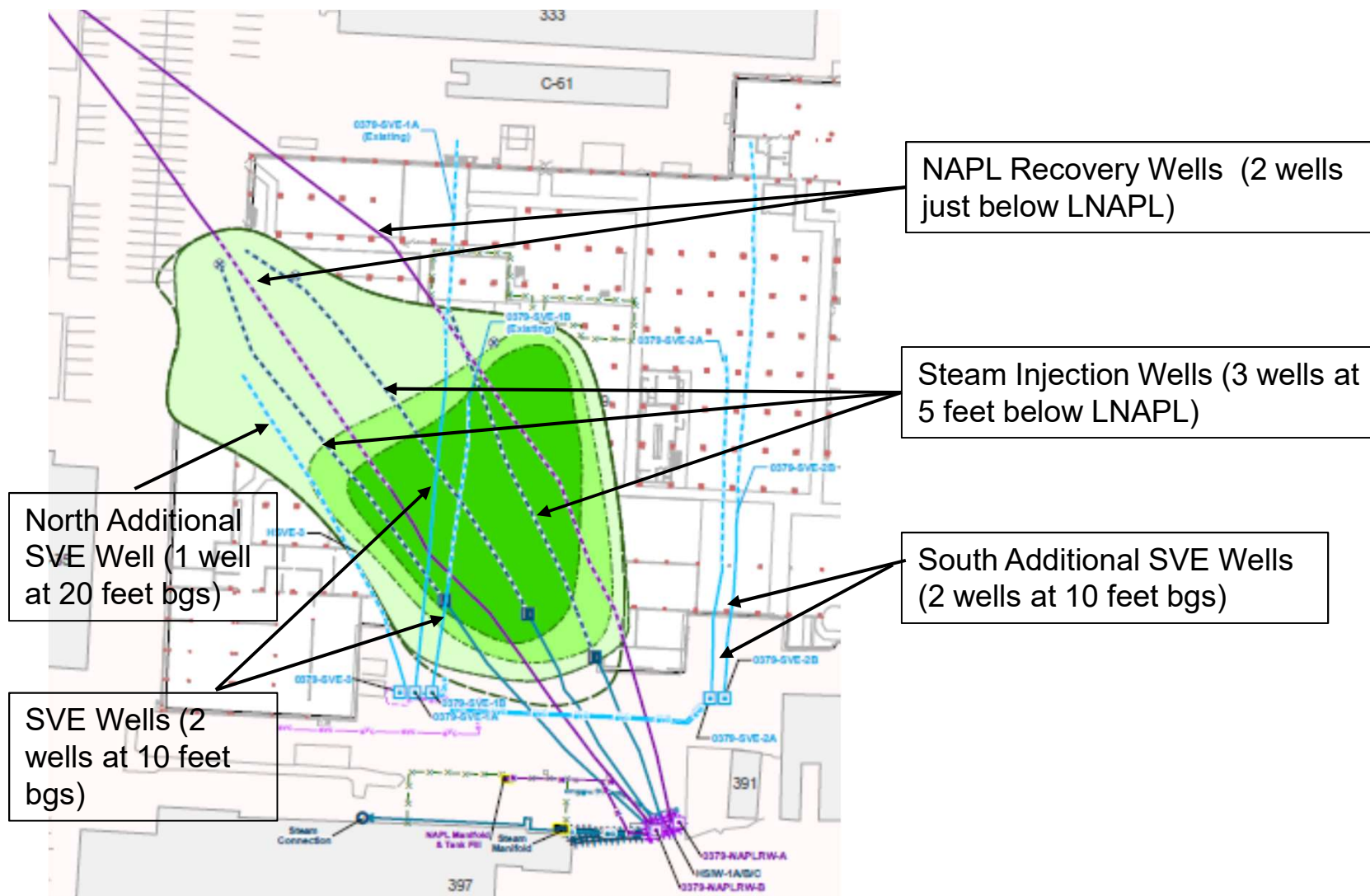
- Temperatures of NAPL near the steam line have increased to as high as 45 °C (113 °F)– likely exacerbated levels of VOCs in sub-slab soil vapor (11,000,000 µg/m<sup>3</sup>)
- Responses was to consider implementing engineering measures to mitigate the effect

But then, the following were considered:

- The NAPL plume footprint has shrunk in past few years (but was stable for several years prior)
- Levels of cis-1,2-DCE within LNAPL have increased significantly within the LNAPL, coupled with a decrease in TCE – likely due to biodegradation of TCE with the TPH serving as electron donor; which may have been caused or enhanced by the elevated temperatures

***Based on this, instead of mitigating the effects of steam, it was decided to add more steam to the subsurface!***

# Remedial Activities





# Knowledge Check



**Steam lines can have a significant effect on volatile LNAPL compounds?**

- a) True**
- b) False**

**Evidence for biodegradation of volatile compounds can be found in NAPL?**

- a) True**
- b) False**

# Key Findings



- SVE with horizontal wells at 10 feet bgs is having a significant impact on cVOCs in LNAPL at 23 feet bgs (cVOCs are the risk drivers) (this was not expected) – likely due to sealing of cracks/joints in floor
- Levels of cVOCs in sub-slab soil vapor (while SVE is on) are orders of magnitude below baseline
- Operation of 2 wells in the northern portion was adequate to decrease indoor air cVOCs to acceptable levels
- The Base steam line (6 feet bgs) is heating up the LNAPL (23 feet bgs) to over 38 °C (100 °F), apparently by conduction through soil column
- TCE in the LNAPL is biodegrading to cDCE, either caused or enhanced by the steam (this was not expected)

# Contacts and Questions



## Points of Contact

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## Questions ?